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Fujita et al.

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(54) **MULTI-HOP COMMUNICATION TERMINAL, MULTI-HOP COMMUNICATION SYSTEM, AND MULTI-HOP COMMUNICATION METHOD**

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H04W 40/22 (2009.01)

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CPC ***H04W 40/08*** (2013.01); ***H04W 40/22*** (2013.01)

(58) **Field of Classification Search**
None
See application file for complete search history.

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(57) **ABSTRACT**

In a gateway (GW), when interference is detected by an interference detection unit, a frame generation unit sends an interference broadcast signal. A terminal receives the interference broadcast signal sent at a maximum transmission power from the GW to which the terminal belongs. The interference broadcast signal includes information on a planned transmission power value that is a transmission power value of a data signal in the GW and is smaller than the maximum transmission power value. The interference broadcast signal is sent at the maximum transmission power value.

4 Claims, 9 Drawing Sheets

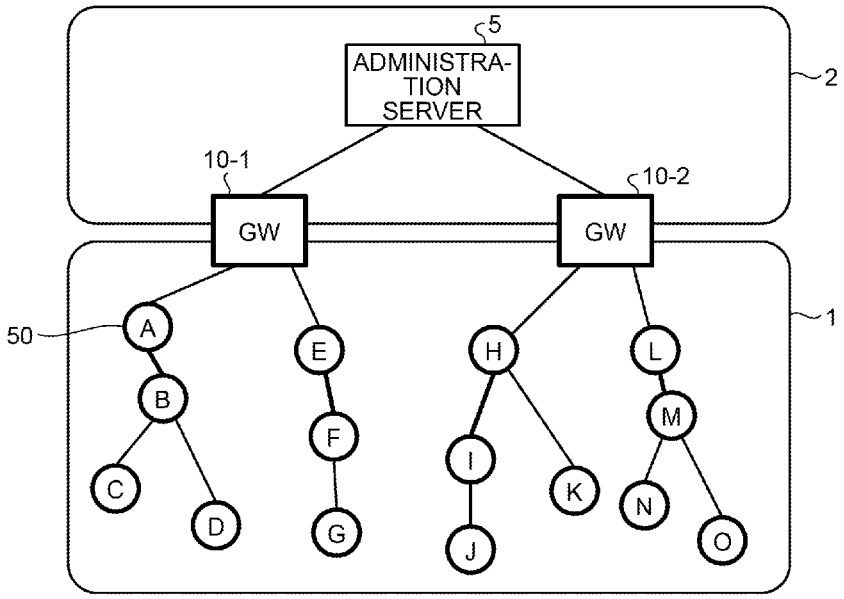


FIG.1

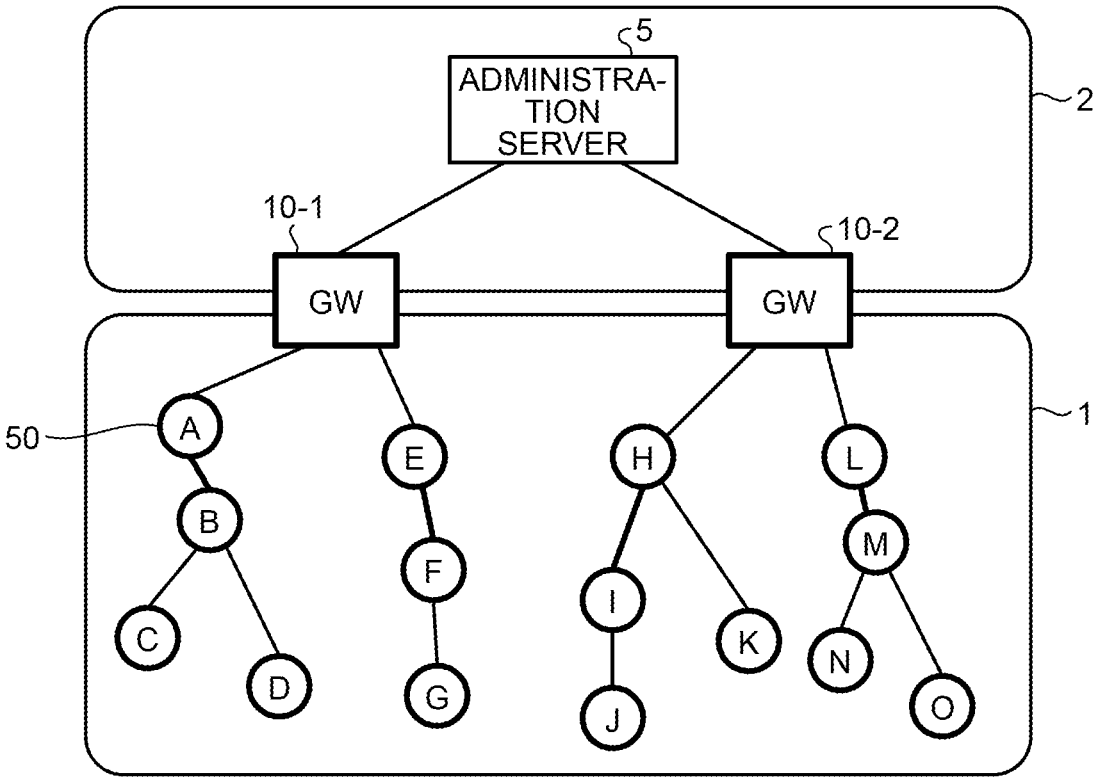

5
ADMINISTRA-
TION
SERVER
2
10-1
10-2
GW
GW
50
1
A
B
C
D
E
F
G
H
I
J
K
L
M
N
O

FIG.2

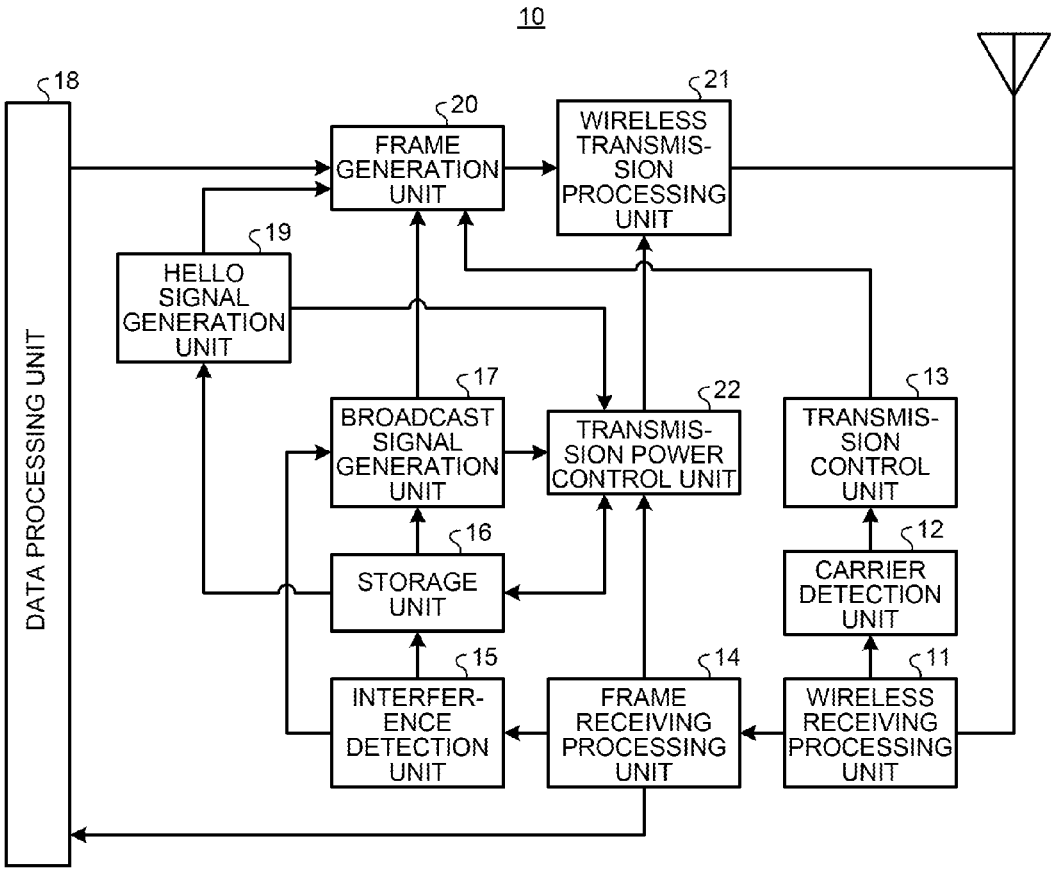

10
18
DATA PROCESSING UNIT
20
FRAME GENERATION UNIT
21
WIRELESS TRANSMIS-SION PROCESSING UNIT
19
HELLO SIGNAL GENERATION UNIT
17
BROADCAST SIGNAL GENERATION UNIT
22
TRANSMIS-SION POWER CONTROL UNIT
13
TRANSMIS-SION CONTROL UNIT
16
STORAGE UNIT
12
CARRIER DETECTION UNIT
15
INTERFER-ENCE DETECTION UNIT
14
FRAME RECEIVING PROCESSING UNIT
11
WIRELESS RECEIVING PROCESSING UNIT

FIG.3

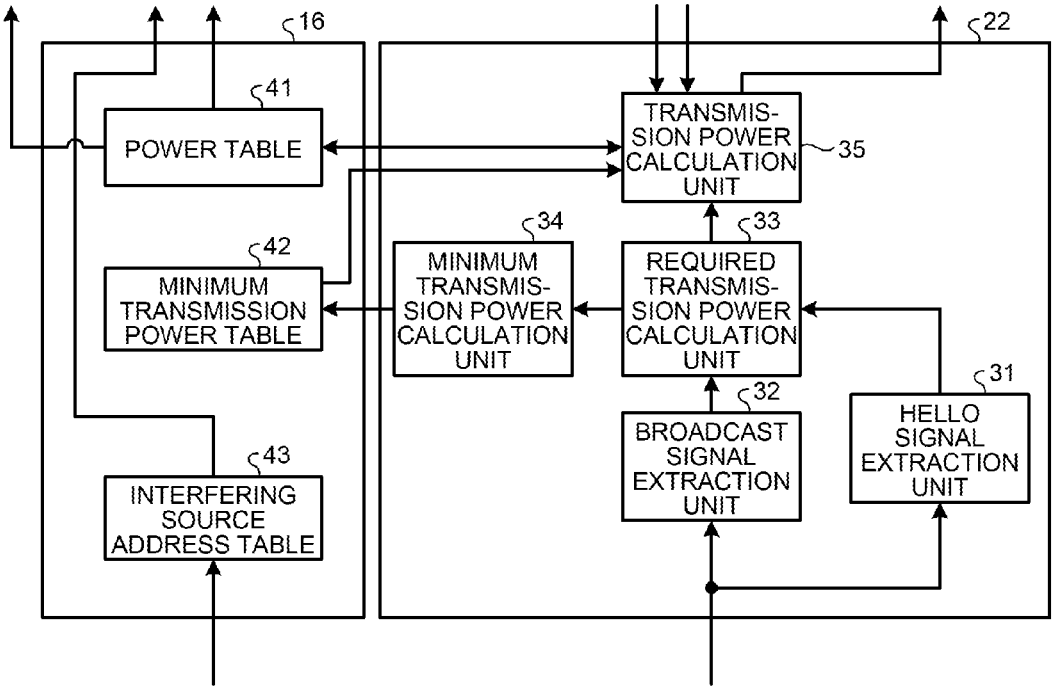

16
22
41
POWER TABLE
TRANSMIS-
SION POWER
CALCULATION
UNIT
35
42
MINIMUM
TRANSMISSION
POWER TABLE
34
MINIMUM
TRANSMIS-
SION POWER
CALCULATION
UNIT
33
REQUIRED
TRANSMIS-
SION POWER
CALCULATION
UNIT
31
HELLO
SIGNAL
EXTRACTION
UNIT
32
BROADCAST
SIGNAL
EXTRACTION
UNIT
43
INTERFERING
SOURCE
ADDRESS TABLE

FIG.4

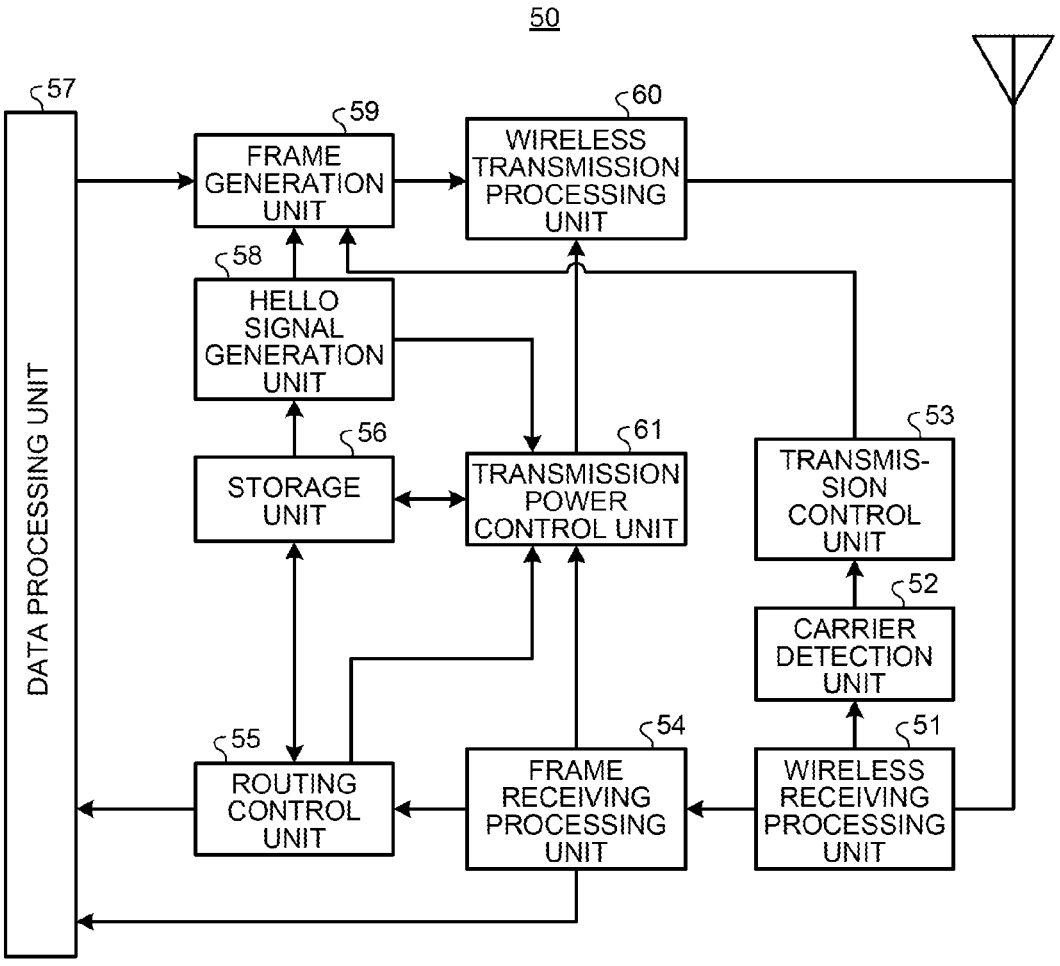

50
57
DATA PROCESSING UNIT
59
FRAME GENERATION UNIT
60
WIRELESS TRANSMISSION PROCESSING UNIT
58
HELLO SIGNAL GENERATION UNIT
56
STORAGE UNIT
61
TRANSMISSION POWER CONTROL UNIT
53
TRANSMIS-SION CONTROL UNIT
52
CARRIER DETECTION UNIT
55
ROUTING CONTROL UNIT
54
FRAME RECEIVING PROCESSING UNIT
51
WIRELESS RECEIVING PROCESSING UNIT

FIG.5

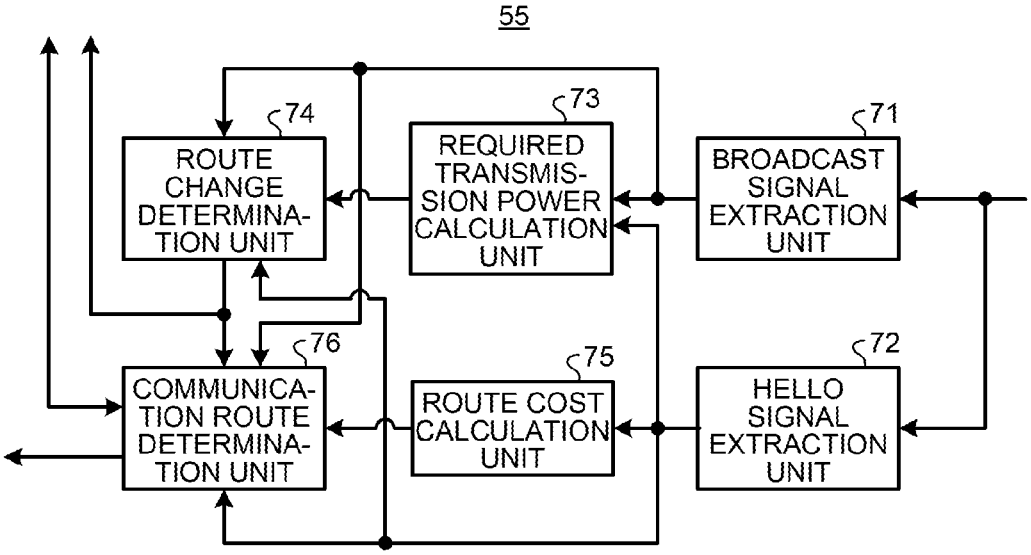

55
74
ROUTE CHANGE DETERMINATION UNIT
73
REQUIRED TRANSMISSION POWER CALCULATION UNIT
71
BROADCAST SIGNAL EXTRACTION UNIT
76
COMMUNICATION ROUTE DETERMINATION UNIT
75
ROUTE COST CALCULATION UNIT
72
HELLO SIGNAL EXTRACTION UNIT

FIG.6

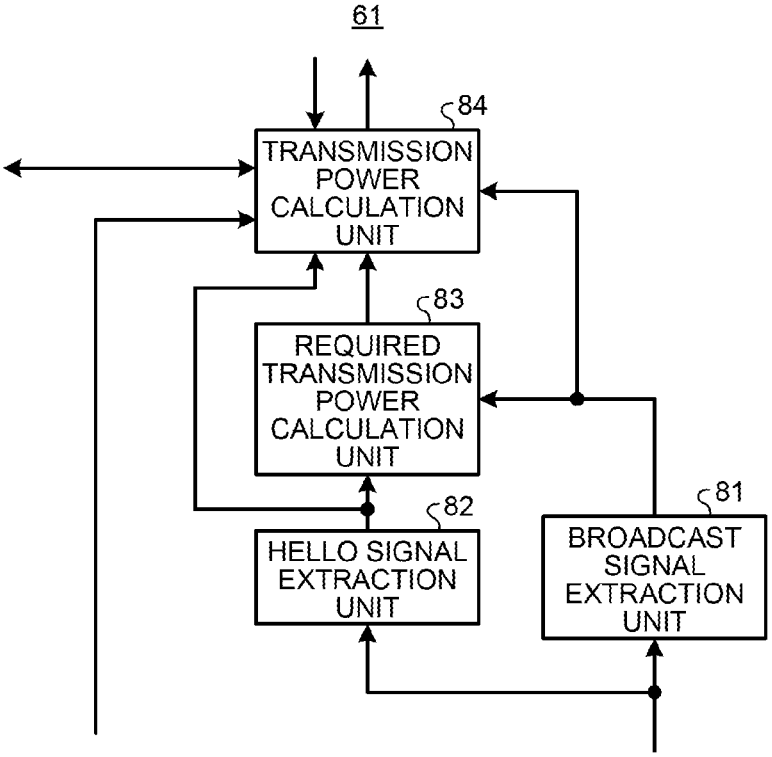

61
84
TRANSMISSION POWER CALCULATION UNIT
83
REQUIRED TRANSMISSION POWER CALCULATION UNIT
82
HELLO SIGNAL EXTRACTION UNIT
81
BROADCAST SIGNAL EXTRACTION UNIT

FIG.7

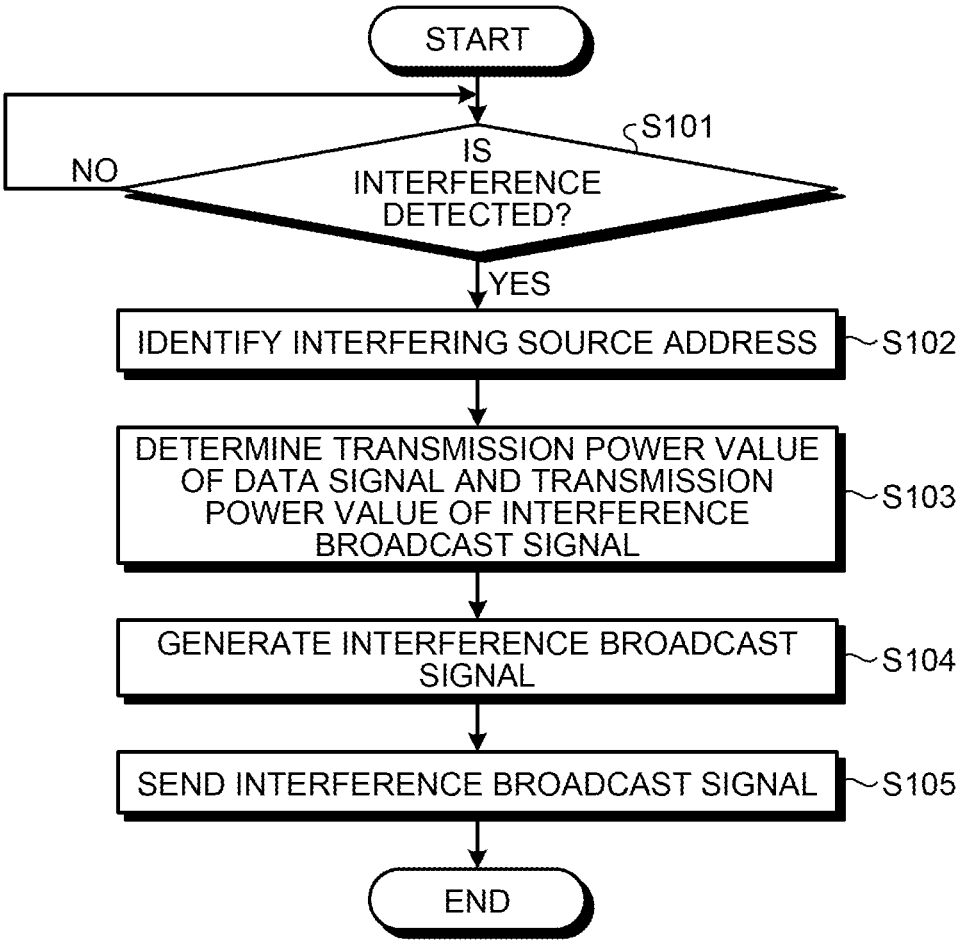

START
S101
IS INTERFERENCE DETECTED?
NO
YES
IDENTIFY INTERFERING SOURCE ADDRESS
S102
DETERMINE TRANSMISSION POWER VALUE OF DATA SIGNAL AND TRANSMISSION POWER VALUE OF INTERFERENCE BROADCAST SIGNAL
S103
GENERATE INTERFERENCE BROADCAST SIGNAL
S104
SEND INTERFERENCE BROADCAST SIGNAL
S105
END

FIG.8

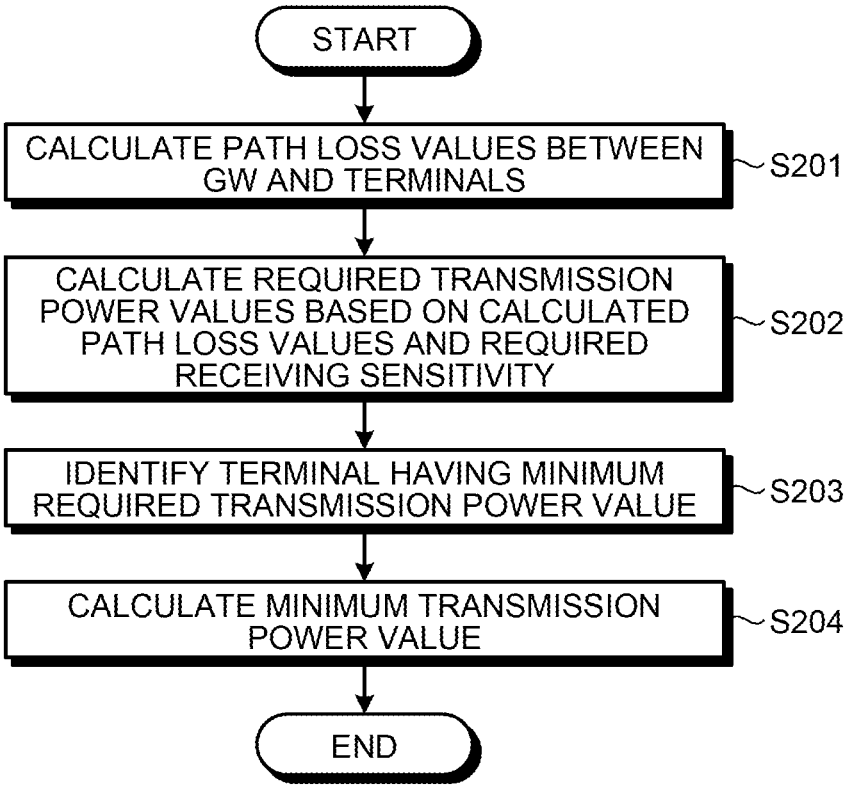

START
CALCULATE PATH LOSS VALUES BETWEEN GW AND TERMINALS
S201
CALCULATE REQUIRED TRANSMISSION POWER VALUES BASED ON CALCULATED PATH LOSS VALUES AND REQUIRED RECEIVING SENSITIVITY
S202
IDENTIFY TERMINAL HAVING MINIMUM REQUIRED TRANSMISSION POWER VALUE
S203
CALCULATE MINIMUM TRANSMISSION POWER VALUE
S204
END

FIG.9

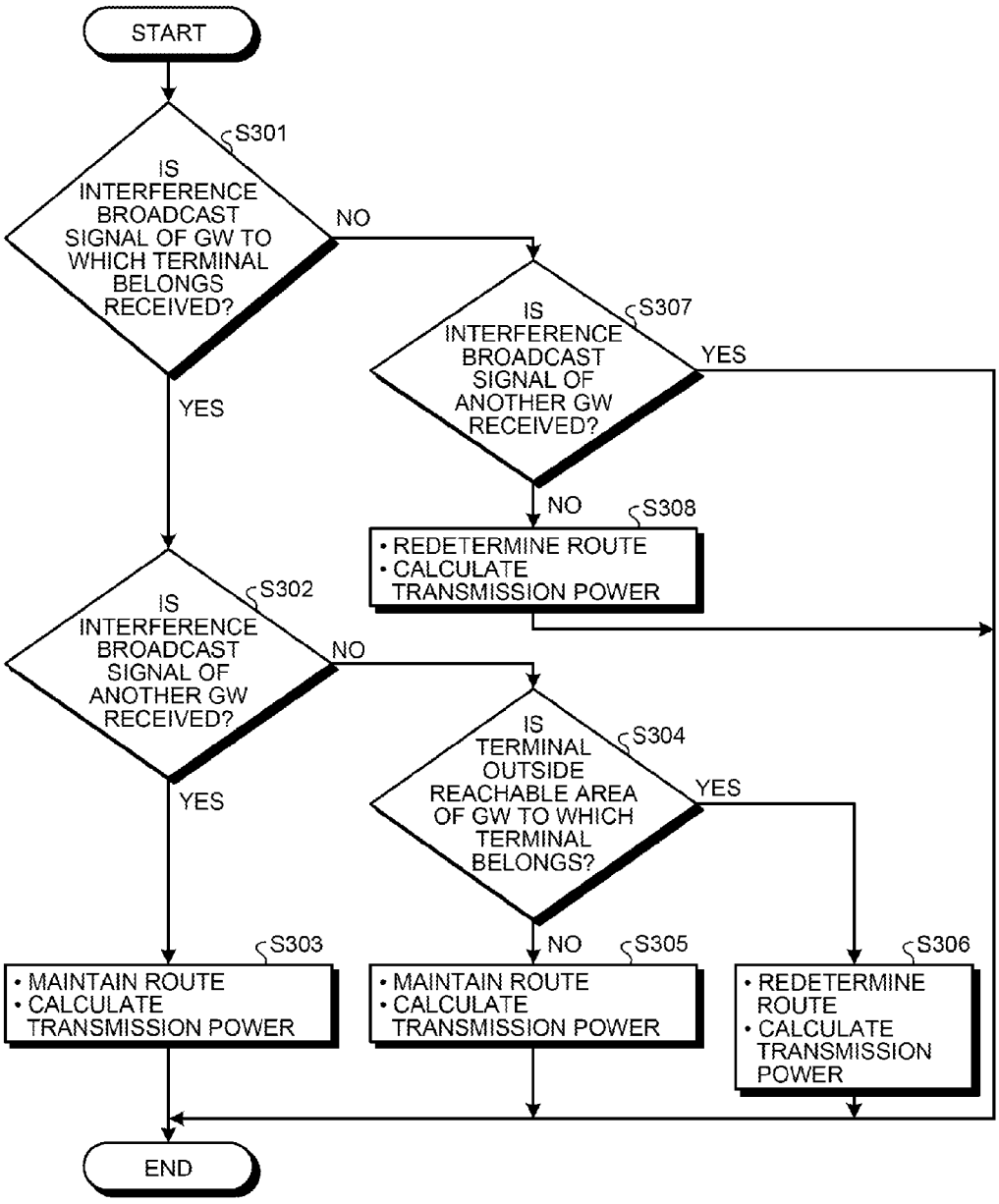

START
S301
IS INTERFERENCE BROADCAST SIGNAL OF GW TO WHICH TERMINAL BELONGS RECEIVED?
NO
YES
S307
IS INTERFERENCE BROADCAST SIGNAL OF ANOTHER GW RECEIVED?
YES
NO
S308
• REDETERMINE ROUTE
• CALCULATE TRANSMISSION POWER
S302
IS INTERFERENCE BROADCAST SIGNAL OF ANOTHER GW RECEIVED?
NO
YES
S304
IS TERMINAL OUTSIDE REACHABLE AREA OF GW TO WHICH TERMINAL BELONGS?
YES
NO
S303
• MAINTAIN ROUTE
• CALCULATE TRANSMISSION POWER
S305
• MAINTAIN ROUTE
• CALCULATE TRANSMISSION POWER
S306
• REDETERMINE ROUTE
• CALCULATE TRANSMISSION POWER
END

FIG.10

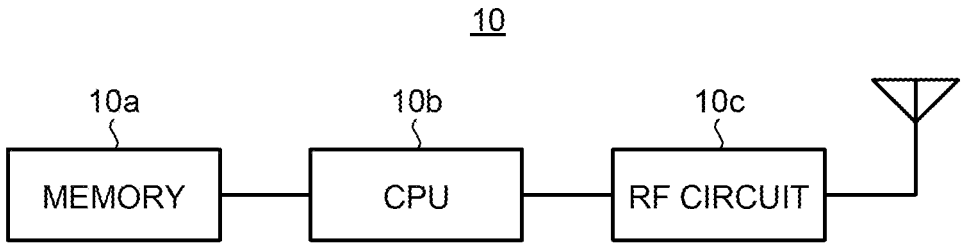
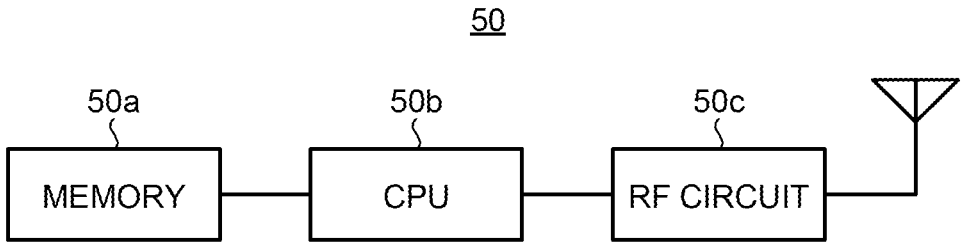

10
10a
10b
10c
MEMORY
CPU
RF CIRCUIT

FIG.11


50
50a
50b
50c
MEMORY
CPU
RF CIRCUIT

MULTI-HOP COMMUNICATION TERMINAL, MULTI-HOP COMMUNICATION SYSTEM, AND MULTI-HOP COMMUNICATION METHOD

CROSS-REFERENCE TO RELATED APPLICATION(S)

This application is based upon and claims the benefit of priority of the prior Japanese Patent Application No. 2012-252595, filed on Nov. 16, 2012, the entire contents of which are incorporated herein by reference.

FIELD

The embodiments discussed herein are related to a multi-hop communication terminal, a multi-hop communication system, and a multi-hop communication method.

BACKGROUND

In recent years, sensor networks have been more and more used for the purpose of monitoring various types of information for managing residential environment, nature conservation, healthcare, traffic conditions, etc. In a sensor network, sensors having a communication function (may be called "sensor terminals" hereinafter) are disposed at various places, and the sensor terminals autonomously constitute the network. Each of the sensor terminals wirelessly communicates with surrounding sensor terminals using a random access method. A carrier sense multiple access/collision avoidance (CSMA/CA) method is an example method for the random access communication. Each of the sensor terminals identifies a terminal to which data is to be sent (that is, a relay terminal) among the surrounding sensor terminals according to a certain method for selecting a communication route, and thus selects a communication route. The sensor terminals in the sensor network constitute a wireless multi-hop network in this manner. The wireless multi-hop network is a wireless network in which each node has a function to transfer data, and nodes that are impossible to directly communicate with each other can communicate via a relay node. Each of the sensor terminals sends data to a destination device using multiple hops. The wireless multi-hop network is sometimes called an ad-hoc network.

Here, in the CSMA/CA method, before starting communication, each of the nodes performs carrier sensing to monitor a received signal strength indication (RSSI). When the detected RSSI is less than a certain value, or the RSSI is not detected, each of the nodes determines that no other node is sending data, and thus sends data. However, the CSMA/CA method has a problem of collision that occurs between a signal sent from a sending node to a destination node and a signal sent from a node that is in an area directly communicable with the destination node but is impossible to detect the transmission by the sending node. The collision may be called interference. The node in which a power of received signal transmitted from the sending node is less than a threshold value may be called a "hidden node".

The wireless multi-hop network includes a tree-type network and a mesh-type network. The tree-type network includes a plurality of terminals and a gateway (GW) that is an information gathering station bundling the terminals. Existence of terminals at a high density under one gateway can produce traffic that is not accommodated by one gateway. In this case, additional installation of a new other gateway can increase the amount of traffic accommodated as a system, that is, the traffic capacity of the system.

However, when the newly added gateway is installed in an area from which an electromagnetic wave reaches the existing gateway, both of the gateways become competitors trying to acquire a wireless resource according to the CSMA/CA method. Specifically, while one of the gateways performs communication, the other gateway waits, and, as a result, is impossible to receive data directed to the other gateway itself, until the communication is terminated. Therefore, in such a case, adding the new gateway does not result in increasing the traffic capacity of the overall system.

There are conventionally methods to control transmission power of a plurality of terminals in the mesh-type network so as to suppress the interference between signals sent from the terminals. Conventional examples are described in Japanese Laid-open Patent Publication No. 2011-146850 and Japanese Laid-open Patent Publication No. 2011-254191.

However, simple application of the conventional interference suppression methods to the tree-type network causes a gateway to give a higher priority to quality of communication with a terminal directly communicating with the gateway itself than to suppression of the interference to other gateways through reduction in the transmission power. Therefore, the gateway giving interference to the other gateways reduces the transmission power thereof only to an extent that does not degrade the quality of communication with the terminal directly communicating with the gateway itself. As a result, the interference between signals sent from the gateways is not suppressed.

When the gateway simply reduces the transmission power to suppress the interference between the signals sent from the gateways, the communication with the terminal directly communicating with the gateway can be disconnected.

SUMMARY

According to an aspect of an embodiment, a multi-hop communication terminal that communicates with a gateway to which the multi-hop communication terminal belongs via a communication route that is an indirect route including at least one other terminal or a direct route. The multi-hop communication terminal includes a receiving unit and a routing control unit. The receiving unit receives:

a first broadcast signal that is sent at a first transmission power value from the gateway to which the multi-hop communication terminal belongs and that includes information on a first planned transmission power value of a data signal in the gateway to which the multi-hop communication terminal belongs, the first planned transmission power value being smaller than the first transmission power value; and a hello signal that includes type information and identification information of a node other than the terminal, and information on a second planned transmission power value of a data signal in the other node. The routing control unit determines the communication route based on the received first broadcast signal and the received hello signal.

The object and advantages of the invention will be realized and attained by means of the elements and combinations particularly pointed out in the claims.

It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory and are not restrictive of the invention, as claimed.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** is a diagram illustrating an example of a multi-hop communication system of a first embodiment of the present invention;

FIG. **2** is a block diagram illustrating an example of a gateway of the first embodiment;

FIG. **3** is a block diagram illustrating an example of a transmission power control unit and a storage unit in the gateway;

FIG. **4** is a block diagram illustrating an example of a multi-hop communication terminal of the first embodiment;

FIG. **5** is a block diagram illustrating an example of a routing control unit in the terminal;

FIG. **6** is a block diagram illustrating an example of a transmission power control unit in the terminal;

FIG. **7** is a flowchart for explaining a transmission process of an interference broadcast signal and a control process of a power transmission value of a data signal performed by the gateway;

FIG. **8** is a flowchart for explaining a calculation process of a minimum transmission power value;

FIG. **9** is a chart for explaining a determination process of a communication route and a control process of a transmission power value of a data signal performed by the terminal;

FIG. **10** is a diagram illustrating a hardware configuration of the gateway; and

FIG. **11** is a diagram illustrating a hardware configuration of the terminal.

DESCRIPTION OF EMBODIMENT(S)

Preferred embodiments of the present invention will be explained with reference to accompanying drawings.

Note that the embodiments do not limit the multi-hop communication terminal, the multi-hop communication system, and the multi-hop communication method disclosed by the present application. Note also that, in the embodiments, the same numerals will be given to configurations having the same functions, and duplicate descriptions thereof will be omitted.

[a] First Embodiment

Overview of Multi-Hop Communication System

FIG. **1** is a diagram illustrating an example of the multi-hop communication system of a first embodiment of the present invention. FIG. **1** illustrates a wireless multi-hop network **1** and a wired network **2**. The wireless multi-hop network **1** includes a plurality of nodes. The nodes include a plurality of gateways (GWs) **10** and a plurality of multi-hop communication terminals **50**. The wireless multi-hop network **1** and the wired network **2** are connected via the GWs **10**. The multi-hop communication system may be hereinafter simply called the communications system. The multi-hop communication terminals may also be simply called the terminals.

The wired network **2** is an internet protocol (IP) network that performs data communication based on the IP, etc., and includes an administration server **5** connected to the GWs **10**. The administration server **5** is a server device that collects data detected in the wireless multi-hop network **1** and performs power supply management, abnormality detection, etc. of the nodes in the wireless multi-hop network **1**.

In FIG. **1**, the wireless multi-hop network **1** includes nodes A to G as the terminals **50** under a GW **10-1**. The wireless multi-hop network **1** also includes nodes H to O as the terminals **50** under a GW **10-2**. Each of the nodes in the wireless multi-hop network **1** selects one node from other nodes existing in a range (may be called a "reachable area" hereinafter) within reach of a data signal sent from each of the nodes itself, and performs communication via a communication route including the selected node. For example, in FIG. **1**, the node C communicates with the GW **10-1** via a communication route including the nodes B and A.

When a GW **10** out of the GWs **10** detects a signal sent from a node other than the terminals **50** (also called "first hop terminals" hereinafter) directly communicating with the GW, the GW sends an "interference broadcast signal". This interference broadcast signal is broadcast at a "first transmission power value". The first transmission power value is a transmission power value known to all of the nodes, and, for example, a maximum transmission power value of the GWs **10**. The interference broadcast signal includes a "first planned transmission power value" of a data signal to be sent after the interference broadcast signal is sent. The first planned transmission power value is a transmission power value at which the transmission data signal does not reach the node from which the interference is received. In other words, when a GW **10** out of the GWs **10** detects interference from a node other than the first hop terminals, the GW **10** adjusts its own reachable area so as not to include the interfering node.

When having received the interference broadcast signal from another GW **10**, the GW **10** changes a set transmission power value that is set for a data signal from a currently set power value to a transmission power value at which the transmission data signal does not reach the other GW **10**. In other words, the GW **10** adjusts its own reachable area so as not to include the other GW **10** that may be subjected to the interference from the GW **10**.

In this manner, the GW **10** can suppress the interference between the GWs **10** by adjusting its own reachable area using as a trigger the event that the GW detects the interference received by itself, or the GW receives the interference broadcast signal sent from another GW **10**.

The terminal **50** that is currently the first hop terminal may come out of the reachable area of the GW **10** to which the terminal **50** belongs as a result of the adjustment of the reachable area by the GW **10**. The terminal **50** coming out of the reachable area of the GW **10** to which the terminal **50** belongs as described above resets the communication route and adjusts the transmission power value. This can allow the terminal **50** coming out of the reachable area of the GW **10** to which the terminal **50** belongs to maintain the communication with the GW **10** to which the terminal **50** belongs via another node. The terminal **50** can determine whether the terminal **50** comes out of the reachable area of the GW **10** to which the terminal **50** belongs by comparing the first planned transmission power value included in the interference broadcast signal sent from the GW **10** to which the terminal **50** belongs with a path loss value between the terminal **50** and the GW **10** to which the terminal **50** belongs. The path loss value can be calculated based on the interference broadcast signal or a hello signal sent from each of the nodes at a "second transmission power value". The second transmission power value is a transmission power value known to all of the nodes, and, for example, the maximum transmission power value. The hello signal includes a "second planned transmission power value" of a data signal to be sent from the transmission source node after the hello signal is sent.

When the terminal **50** is still included in the reachable area after adjustment after the reachable area is adjusted by the GW **10** to which the terminal **50** belongs, the terminal **50** sends the data signal at the first planned transmission power value included in the interference broadcast signal sent from the GW **10** to which the terminal **50** belongs. However, when the terminal **50** has received both the interference broadcast signal from the GW **10** to which the terminal **50** belongs and the interference broadcast signal sent from a GW **10** other

than the GW **10** to which the terminal **50** belongs, the terminal **50** sends the data signal at a transmission power value at which the transmission data signal reaches the GW **10** to which the terminal **50** belongs but does not reach the other GW **10**. The terminal **50** that has received both the interference broadcast signal from the GW **10** to which the terminal **50** belongs and the interference broadcast signal sent from a GW **10** other than the GW **10** to which the terminal **50** belongs refers to a terminal included in the reachable area of both of the GW **10** to which the terminal **50** belongs and the other GW **10**.

When the terminal **50** has not received the interference broadcast signal from either the GW **10** to which the terminal **50** belongs or any other GW **10**, the terminal **50** resets the communication route and sets the transmission power value when a certain condition is satisfied. The terminal **50** that has not received the interference broadcast signal from either the GW **10** to which the terminal **50** belongs or any other GW **10** refers to a terminal that is included in neither of the reachable areas.

As described above, the GW **10** sends the above-described interference broadcast signal when the interference is detected, and the terminal **50** resets the communication route and sets the transmission power value based on the interference broadcast signal of the GW **10** to which the terminal **50** belongs, the interference broadcast signal of the other GW **10**, and the hello signal of a node other than the terminal **50**. This can prevent the interference between the gateways, and can allow the terminal directly communicating with the gateway to maintain the communication.

Configuration of Gateway

FIG. **2** is a block diagram illustrating an example of the gateway of the first embodiment. In FIG. **2**, the GW **10** includes a wireless receiving processing unit **11**, a carrier detection unit **12**, a transmission control unit **13**, a frame receiving processing unit **14**, an interference detection unit **15**, and a storage unit **16**. The GW **10** further includes a broadcast signal generation unit **17**, a data processing unit **18**, a hello signal generation unit **19**, a frame generation unit **20**, a wireless transmission processing unit **21**, and a transmission power control unit **22**. The GW **10** also includes an interface (not illustrated) connected to the wired network.

The wireless receiving processing unit **11** outputs a wireless signal received via an antenna to the carrier detection unit **12**. The wireless receiving processing unit **11** also applies wireless receiving processing, such as down-conversion and analog-digital (AD) conversion, to the wireless signal received via the antenna, and outputs the received signal after the wireless receiving processing to the frame receiving processing unit **14**.

Based on the power of the signal received from the wireless receiving processing unit **11**, the carrier detection unit **12** determines whether other nodes are sending signals, and outputs the determination result to the transmission control unit **13**.

Based on the determination result received from the carrier detection unit **12**, the transmission control unit **13** controls transmission timing of a signal to be sent from the GW **10**. For example, the transmission control unit **13** outputs a transmission command signal to the frame generation unit **20** at the time when other nodes are not sending signals. The frame generation unit **20** sends the signal according to the transmission command signal. Thus, the GW **10** sends the transmission signal in a period when other nodes are not sending signals.

The frame receiving processing unit **14** switches the output destinations depending on the type of the signal received from the wireless receiving processing unit **11**. For example, the frame receiving processing unit **14** outputs a data signal directed to the GW **10** to the data processing unit **18**. The frame receiving processing unit **14** outputs a data signal directed not to the GW **10** but to another node to the interference detection unit **15**. The frame receiving processing unit **14** outputs, to the transmission power control unit **22**, the interference broadcast signal sent from another GW **10** and the hello signal sent from a node other than the GW **10**.

Based on the data signal received from the frame receiving processing unit **14**, the interference detection unit **15** detects interference from a node other than the first hop terminals of the GW **10**, and identifies identification information of the interfering node (that is, the interfering source address). The identified interfering source address is stored into the storage unit **16**. The storage unit **16** stores therein a table (not illustrated) that holds identification information of the first hop terminals of the GW **10**. Comparing the identification information held in this table with the identification information of the interfering node enables determination of whether the interfering node is a node in the first hop terminals of the GW **10**. In addition, inclusion of a node type in the identification information of the node enables determination of whether the interfering node is another GW **10** or one of the terminals **50**. The interference detection unit **15** may determine that it has detected interference when a data signal sent from one interfering node is detected at a certain time. The interference detection unit **15** may alternatively determine that it has detected interference when data signals sent from one interfering node are continuously detected during a certain period starting from a first time point. In this case, the certain period is measured by a timer (not illustrated).

When having detected the interference from the node other than the first hop terminals of the GW **10**, the interference detection unit **15** outputs a detection notification signal to the broadcast signal generation unit **17**.

After receiving the detection notification signal from the interference detection unit **15**, the broadcast signal generation unit **17** generates an interference broadcast signal. As described above, this interference broadcast signal includes the "first planned transmission power value" of a data signal to be sent after the interference broadcast signal is sent. The first planned transmission power value is a transmission power value at which the data signal does not reach the detected interfering node. The first planned transmission power value has been calculated by the transmission power control unit **22** and stored in the storage unit **16**.

Then, the broadcast signal generation unit **17** outputs the generated interference broadcast signal to the frame generation unit **20**, and outputs a generation completion notification to the transmission power control unit **22**. After receiving the generation completion notification, the transmission power control unit **22** sets the transmission power value to be set for the wireless transmission processing unit **21** to the maximum transmission power value. This causes the interference broadcast signal to be sent at the maximum transmission power. Although the interference broadcast signal has been described here as being sent at the maximum transmission power value, the transmission power value may be a transmission power value known to all of the nodes other than the maximum transmission power value, as described above.

The data processing unit **18** applies certain processing, such as decoding, to the data signal received from the frame receiving processing unit **14**. The data processing unit **18** also generates user data, and outputs it to the frame generation unit **20**.

The hello signal generation unit **19** generates a hello signal. The hello signal includes the "second planned transmission power value" of a data signal to be sent from the GW **10** after the hello signal is sent. The second planned transmission power value has been calculated by the transmission power control unit **22** and stored in the storage unit **16**.

Then, the hello signal generation unit **19** outputs the generated hello signal to the frame generation unit **20**, and outputs a generation completion notification to the transmission power control unit **22**. After receiving the generation completion notification, the transmission power control unit **22** sets the transmission power value to be set for the wireless transmission processing unit **21** to the maximum transmission power value. This causes also the hello signal to be sent at the maximum transmission power value. Although the hello signal has been described here as being sent at the maximum transmission power value, the transmission power value may be a transmission power value known to all of the nodes other than the maximum transmission power value, as described above.

The frame generation unit **20** generates a frame signal by mapping, to a wireless frame, the data signal, the interference broadcast signal, and the hello signal that have been received, and outputs the generated frame signal to the wireless transmission processing unit **21** at the time in accordance with the transmission command signal. When interference by any interfering node has caused the interference broadcast signal to be sent a number of times exceeding a certain threshold value, that is, when interference by any interfering node has been detected a number of times exceeding the certain value, the frame generation unit **20** may exclude, from signals to be retransmitted, the interference broadcast signal indicating the interference by the interfering node.

The wireless transmission processing unit **21** applies certain wireless transmission processing, such as digital-analog (DA) conversion, up-conversion, and amplification, to the frame signal received from the frame generation unit **20**, and sends the obtained wireless signal via the antenna. Here, the wireless signal is sent after being amplified to the transmission power value set by the transmission power control unit **22**.

The transmission power control unit **22** determines the transmission power value of the data signal in the GW **10** based on the interference broadcast signal sent from another GW **10**, or based on the hello signal sent from another GW **10**.

When the interference detection unit **15** has detected interference from other nodes, the transmission power control unit **22** calculates the transmission power value of the data signal in the GW **10** based on the hello signals sent from the interfering nodes.

Here, the transmission power control unit **22** assumes, as the lower limit value of the transmission power value of the data signal in the GW **10**, the minimum value among required transmission power values each of which is calculated from a path loss value calculated based on a hello signal and from required receiving sensitivity for each of the terminals **50** serving as transmission source nodes of the hello signals.

For example, as illustrated in FIG. **3**, the transmission power control unit **22** includes a hello signal extraction unit **31**, a broadcast signal extraction unit **32**, a required transmission power calculation unit **33**, a minimum transmission power calculation unit **34**, and a transmission power calculation unit **35**. FIG. **3** is a block diagram illustrating an example of the transmission power control unit and the storage unit in the gateway.

The hello signal extraction unit **31** extracts the hello signal from the signals received from the frame receiving processing unit **14**, and identifies the identification information of the transmission source node of the extracted hello signal. Then, the hello signal extraction unit **31** outputs the extracted hello signal and the identified identification information of the transmission source node as a set to the required transmission power calculation unit **33**.

The broadcast signal extraction unit **32** extracts the interference broadcast signal from the signals received from the frame receiving processing unit **14**, and identifies the identification information of another GW **10** that is the transmission source of the extracted interference broadcast signal. Then, the broadcast signal extraction unit **32** outputs the extracted interference broadcast signal and the identified identification information of the other GW **10** as a set to the required transmission power calculation unit **33**.

The required transmission power calculation unit **33** calculates the path loss value between the GW **10** and the transmission source node of the hello signal based on the receiving power value of the hello signal received from the hello signal extraction unit **31**. For example, the path loss value can be calculated by subtracting the receiving power value from the transmission power value of the hello signal, which is already known.

The required transmission power calculation unit **33** also calculates the path loss value between the GW **10** and the other GW **10** serving as the transmission source of the interference broadcast signal based on the receiving power value of the interference broadcast signal received from the broadcast signal extraction unit **32**. For example, the path loss value can be calculated by subtracting the receiving power value from the transmission power value of the interference broadcast signal, which is already known.

Then, based on the calculated path loss value and the required receiving sensitivity, the required transmission power calculation unit **33** calculates the required transmission power value.

Then, the required transmission power calculation unit **33** outputs, to the transmission power calculation unit **35** and the minimum transmission power calculation unit **34**, the calculated required transmission power value and the identification information of the transmission source node corresponding to the required transmission power value, in a manner associated with each other.

The minimum transmission power calculation unit **34** identifies the minimum value among the required transmission power values for the terminals **50** received from the required transmission power calculation unit **33**, and outputs the identified minimum value and the identification information of the terminal **50** corresponding thereto to the storage unit **16**. This causes the storage unit **16** to store therein the identified minimum value and the identification information of the terminal **50** corresponding thereto. The GW **10** can now directly communicate with at least one of the terminals **50** by setting the transmission power value to this minimum value or more.

Based on the required transmission power value calculated by the required transmission power calculation unit **33**, the transmission power calculation unit **35** calculates the transmission power value of the data signal in the GW **10**, and outputs the calculated transmission power value in the storage unit **16**. This causes the storage unit **16** to store therein the calculated transmission power value. When the transmission power calculation unit **35** has received the generation completion notification from the broadcast signal generation unit **17** or the hello signal generation unit **19**, the transmission power calculation unit **35** reads the maximum transmission power value stored in the storage unit **16**, and sets the maxi-

mum transmission power value for the wireless transmission processing unit **21**. At the time of data transmission, the transmission power calculation unit **35** sets the calculated transmission power value of the data signal for the wireless transmission processing unit **21**.

Referring back to FIG. **2**, the storage unit **16** stores therein the maximum transmission power value and the transmission power value that is calculated by the transmission power calculation unit **35**. The storage unit **16** also stores therein the minimum value calculated by the minimum transmission power calculation unit **34**. The storage unit **16** also stores therein the interfering source address identified by the interference detection unit **15**.

For example, as illustrated in FIG. **3**, the storage unit **16** includes a power table **41**, a minimum transmission power table **42**, and an interfering source address table **43**. The power table **41** holds the maximum transmission power value and the transmission power value that is calculated by the transmission power calculation unit **35**. The minimum transmission power table **42** holds the minimum value calculated by the minimum transmission power calculation unit **34**. The interfering source address table **43** holds the interfering source address identified by the interference detection unit **15**.

Configuration of Terminal

FIG. **4** is a block diagram illustrating an example of the multi-hop communication terminal of the first embodiment. In FIG. **4**, the terminal **50** includes a wireless receiving processing unit **51**, a carrier detection unit **52**, a transmission control unit **53**, a frame receiving processing unit **54**, a routing control unit **55**, and a storage unit **56**. The terminal **50** further includes a data processing unit **57**, a hello signal generation unit **58**, a frame generation unit **59**, a wireless transmission processing unit **60**, and a transmission power control unit **61**.

The wireless receiving processing unit **51** outputs a wireless signal received via an antenna to the carrier detection unit **52**. The wireless receiving processing unit **51** also applies wireless receiving processing, such as down-conversion and analog-digital (AD) conversion, to the wireless signal received via the antenna, and outputs the received signal after the wireless receiving processing to the frame receiving processing unit **54**.

Based on the power of the signal received from the wireless receiving processing unit **51**, the carrier detection unit **52** determines whether other nodes are sending signals, and outputs the determination result to the transmission control unit **53**.

Based on the determination result received from the carrier detection unit **52**, the transmission control unit **53** controls transmission timing of a signal to be sent from the terminal **50**. For example, the transmission control unit **53** outputs a transmission command signal to the frame generation unit **59** at the time when other nodes are not sending signals. The frame generation unit **59** sends the signal according to the transmission command signal. Thus, the terminal **50** sends the transmission signal in a period when other nodes are not sending signals.

The frame receiving processing unit **54** switches the output destinations depending on the type of the signal received from the wireless receiving processing unit **51**. For example, the frame receiving processing unit **54** outputs a data signal directed to the terminal **50** to the data processing unit **57**. The frame receiving processing unit **54** outputs, to the routing control unit **55** and the transmission power control unit **61**, the interference broadcast signal sent from the GWs **10** and the hello signal sent from a node other than the terminal **50**.

The routing control unit **55** sets the communication route based on an interference broadcast signal from any GW **10** other than the GW **10** to which the terminal **50** belongs and whether the interference broadcast signal is received, an interference broadcast signal from the GW **10** to which the terminal **50** belongs and whether the interference broadcast signal is received, and the hello signal sent from a node other than the terminal **50**.

For example, when an interference broadcast signal is received from the GW **10** to which the terminal **50** belongs, and no interference broadcast signal is received from any other GW **10**, the routing control unit **55** determines whether the terminal **50** is outside the reachable area of the GW **10** to which the terminal **50** belongs. In this determination, when the routing control unit **55** determines that the first planned transmission power value included in the interference broadcast signal from the GW **10** to which the terminal **50** belongs is smaller than the required transmission power value between the terminal **50** and the GW **10** to which the terminal **50** belongs, the terminal **50** is determined as outside the reachable area of the GW **10** to which the terminal **50** belongs. When the terminal **50** is determined as outside the reachable area of the GW **10** to which the terminal **50** belongs, the routing control unit **55** resets the communication route. At this time, the routing control unit **55** determines, as the communication route, one alternative from a plurality of communication route alternatives including the other terminals **50** existing in the reachable area of the terminal **50** determined by the first planned transmission power value included in the interference broadcast signal from the GW **10** to which the terminal **50** belongs. The criterion for selecting one alternative from the communication route alternatives is a route cost that is calculated for each of the communication route alternatives. When the routing control unit **55** determines that the terminal **50** is not outside the reachable area of the GW **10** to which the terminal **50** belongs, the routing control unit **55** maintains the current communication route, that is, the direct route that directly connects the terminal **50** to the GW **10** to which the terminal **50** belongs.

When both an interference broadcast signal from the GW **10** to which the terminal **50** belongs and an interference broadcast signal from another GW **10** are received, the routing control unit **55** basically maintains the current communication route, that is, the direct route that is directly connected to the GW **10** to which the terminal **50** belongs.

When neither an interference broadcast signal from the GW **10** to which the terminal **50** belongs nor an interference broadcast signal from any other GW **10** is received, the routing control unit **55** resets the communication route when a certain condition is satisfied. The certain condition means that the second planned transmission power value included in the hello signal sent from the first hop terminal for the terminal **50**, that is, the adjacent terminal **50** on the currently set communication route is smaller than the transmission power value that is currently set for sending the data signal of the terminal **50**. At this time, the routing control unit **55** determines, as the communication route, one alternative from a plurality of communication route alternatives including the other terminals **50** existing in the reachable area of the terminal **50** determined by the second planned transmission power value included in the hello signal from the first hop terminal for the terminal **50**. The criterion for selecting one alternative from the communication route alternatives is the route cost that is calculated for each of the communication route alternatives.

In detail, as illustrated in FIG. **5**, the routing control unit **55** includes a broadcast signal extraction unit **71**, a hello signal extraction unit **72**, a required transmission power calculation

unit **73**, a route change determination unit **74**, a route cost calculation unit **75**, and a communication route determination unit **76**. FIG. **5** is a block diagram illustrating an example of the routing control unit in the terminal.

The broadcast signal extraction unit **71** extracts the interference broadcast signal from the signals received from the frame receiving processing unit **54**, and identifies the identification information of the GW **10** that is the transmission source of the extracted interference broadcast signal. Then, the broadcast signal extraction unit **71** outputs the extracted interference broadcast signal and the identified identification information of the GW **10** as a set to the required transmission power calculation unit **73**, the route change determination unit **74**, and the communication route determination unit **76**.

The hello signal extraction unit **72** extracts the hello signal from the signals received from the frame receiving processing unit **54**, and identifies the identification information of the transmission source node of the extracted hello signal. Then, the hello signal extraction unit **72** outputs the extracted hello signal and the identified identification information of the transmission source node as a set to the required transmission power calculation unit **73**, the route change determination unit **74**, the route cost calculation unit **75**, and the communication route determination unit **76**.

The required transmission power calculation unit **73** calculates the path loss value between the terminal **50** and the GW **10** serving as the transmission source of the interference broadcast signal based on the receiving power value of the interference broadcast signal received from the broadcast signal extraction unit **71**. For example, the path loss value can be calculated by subtracting the receiving power value from the transmission power value of the interference broadcast signal, which is already known.

The required transmission power calculation unit **73** also calculates the path loss value between the terminal **50** and the transmission source node of the hello signal based on the receiving power value of the hello signal received from the hello signal extraction unit **72**. For example, the path loss value can be calculated by subtracting the receiving power value from the transmission power value of the hello signal, which is already known.

Then, based on the calculated path loss value and the required receiving sensitivity, the required transmission power calculation unit **73** calculates the required transmission power value.

Then, the required transmission power calculation unit **73** outputs, to the route change determination unit **74**, the calculated required transmission power value and the identification information of the transmission source node corresponding to the required transmission power value, in a manner associated with each other.

When either of the following conditions is satisfied, the route change determination unit **74** determines to change the route.

Condition 1: An interference broadcast signal is received from the GW **10** to which the terminal **50** belongs whereas no interference broadcast signal is received from any other GW **10**, and the terminal **50** is determined as outside the reachable area of the GW **10** to which the terminal **50** belongs.

Condition 2: Neither an interference broadcast signal from the GW **10** to which the terminal **50** belongs nor an interference broadcast signal from any other GW **10** is received, and the second planned transmission power value included in the hello signal from the first hop terminal for the terminal **50** is smaller than the transmission power value that is currently set for the data signal of the terminal **50**.

Then, the route change determination unit **74** outputs the determination result of whether to change the route to the communication route determination unit **76** and the transmission power control unit **61**.

Based on a plurality of hello signals received from the hello signal extraction unit **72**, the route cost calculation unit **75** calculates the route cost of each of the communication route alternatives that include the transmission source nodes of the hello signals as respective adjacent terminals. Here, the route cost refers to, for example, the number of hops on the communication route from the terminal **50** to the GW **10** to which the terminal **50** belongs, that is, the number of terminals **50** existing between the terminal **50** and the GW **10** to which the terminal **50** belongs on the communication route.

Then, the route cost calculation unit **75** outputs the route costs of the respective communication route alternatives and the identification information of the adjacent terminals on the corresponding communication route alternatives as a set to the communication route determination unit **76**.

When Condition 1 above is satisfied, the communication route determination unit **76** identifies a plurality of communication route alternatives that include, as the adjacent terminals, the terminals **50** existing in the reachable area of the terminal **50** determined by the first planned transmission power value included in the interference broadcast signal from the GW **10** to which the terminal **50** belongs. Then, the communication route determination unit **76** determines, as the communication route, the communication route alternative having the smallest route cost among the identified communication route alternatives.

When Condition 2 above is satisfied, the communication route determination unit **76** identifies a plurality of communication route alternatives that include, as the adjacent terminals, the terminals **50** existing in the reachable area of the terminal **50** determined by the second planned transmission power value included in the hello signal sent from the adjacent terminal on the current communication route. Then, the communication route determination unit **76** determines, as the communication route, the communication route alternative having the smallest route cost among the identified communication route alternatives.

In other cases, the communication route determination unit **76** determines to maintain the currently set communication route. The identification information of the GW **10** to which the terminal **50** belongs is read from the storage unit **56**.

Then, the communication route determination unit **76** outputs information on the determined communication route to the data processing unit **57**.

Referring back to FIG. **4**, the data processing unit **57** applies certain processing, such as decoding, to the data signal received from the frame receiving processing unit **54**. The data processing unit **57** also generates user data, and outputs it to the frame generation unit **59**.

The hello signal generation unit **58** generates a hello signal. The hello signal includes the "second planned transmission power value" of a data signal to be sent from the terminal **50** after the hello signal is sent. The second planned transmission power value has been calculated by the transmission power control unit **61** and stored in the storage unit **56**.

Then, the hello signal generation unit **58** outputs the generated hello signal to the frame generation unit **59**, and outputs a generation completion notification to the transmission power control unit **61**. After receiving the generation completion notification, the transmission power control unit **61** sets the transmission power value to be set for the wireless transmission processing unit **60** to the maximum transmission power value. This causes the hello signal to be sent at the

maximum transmission power value. Although the hello signal has been described here as being sent at the maximum transmission power value, the transmission power value may be a transmission power value known to all of the nodes other than the maximum transmission power value, as described above.

The frame generation unit **59** generates a frame signal by mapping, to a wireless frame, the data signal and the hello signal that have been received, and outputs the generated frame signal to the wireless transmission processing unit **60** at the time in accordance with the transmission command signal.

The wireless transmission processing unit **60** applies certain wireless transmission processing, such as digital-analog (DA) conversion, up-conversion, and amplification, to the frame signal received from the frame generation unit **59**, and sends the obtained wireless signal via the antenna. Here, the wireless signal is sent after being amplified to the transmission power value set by the transmission power control unit **61**.

The transmission power control unit **61** sets the transmission power value of the data signal based on an interference broadcast signal from any GW **10** other than the GW **10** to which the terminal **50** belongs and whether the interference broadcast signal is received, an interference broadcast signal from the GW **10** to which the terminal **50** belongs and whether the interference broadcast signal is received, and the hello signal sent from a node other than the terminal **50**.

For example, when an interference broadcast signal is received from the GW **10** to which the terminal **50** belongs, and no interference broadcast signal is received from any other GW **10**, the transmission power control unit **61** determines the first planned transmission power value included in the interference broadcast signal from the GW **10** to which the terminal **50** belongs as the transmission power value of the transmission data of the terminal **50**.

When both an interference broadcast signal from the GW **10** to which the terminal **50** belongs and an interference broadcast signal from another GW **10** are received, the transmission power control unit **61** calculates a transmission power value at which the transmission signal reaches the GW **10** to which the terminal **50** belongs but does not reach the other GW **10**.

When neither an interference broadcast signal from the GW **10** to which the terminal **50** belongs nor an interference broadcast signal from any other GW **10** is received, the transmission power control unit **61** sets, as the transmission power value of the terminal **50**, the second planned transmission power value included in the hello signal from the adjacent terminal on the communication route reset by the routing control unit **55**.

In detail, as illustrated in FIG. **6**, the transmission power control unit **61** includes a broadcast signal extraction unit **81**, a hello signal extraction unit **82**, a required transmission power calculation unit **83**, and a transmission power calculation unit **84**. FIG. **6** is a block diagram illustrating an example of the transmission power control unit in the terminal.

The broadcast signal extraction unit **81** extracts the interference broadcast signal from the signals received from the frame receiving processing unit **54**, and identifies the identification information of the GW **10** that is the transmission source of the extracted interference broadcast signal. Then, the broadcast signal extraction unit **81** outputs the extracted interference broadcast signal and the identified identification information of the GW **10** as a set to the required transmission power calculation unit **83** and the transmission power calculation unit **84**.

The hello signal extraction unit **82** extracts the hello signal from the signals received from the frame receiving processing unit **54**, and identifies the identification information of the transmission source node of the extracted hello signal. Then, the hello signal extraction unit **82** outputs the extracted hello signal and the identified identification information of the transmission source node as a set to the required transmission power calculation unit **83** and the transmission power calculation unit **84**.

The required transmission power calculation unit **83** calculates the path loss value between the terminal **50** and the GW **10** serving as the transmission source of the interference broadcast signal based on the receiving power value of the interference broadcast signal received from the broadcast signal extraction unit **81**.

The required transmission power calculation unit **83** also calculates the path loss value between the terminal **50** and the transmission source node of the hello signal based on the receiving power value of the hello signal received from the hello signal extraction unit **82**.

Based on the calculated path loss value and the required receiving sensitivity, the required transmission power calculation unit **83** calculates the required transmission power value.

Then, the required transmission power calculation unit **83** outputs, to the transmission power calculation unit **84**, the calculated required transmission power value and the identification information of the transmission source node corresponding to the required transmission power value, in a manner associated with each other.

When an interference broadcast signal is received from the GW **10** to which the terminal **50** belongs, and no interference broadcast signal is received from any other GW **10**, the transmission power calculation unit **84** determines the first planned transmission power value included in the interference broadcast signal from the GW **10** to which the terminal **50** belongs as the transmission power value of the transmission data of the terminal **50**.

When both an interference broadcast signal from the GW **10** to which the terminal **50** belongs and an interference broadcast signal from another GW **10** are received, the transmission power calculation unit **84** calculates a transmission power value at which the transmission signal reaches the GW **10** to which the terminal **50** belongs but does not reach the other GW **10**. For example, the transmission power calculation unit **84** determines the transmission power value to be larger than the required transmission power value between the terminal **50** and the GW **10** to which the terminal **50** belongs, and smaller than the required transmission power value between the terminal **50** and the other GW **10**.

When neither an interference broadcast signal from the GW **10** to which the terminal **50** belongs nor an interference broadcast signal from any other GW **10** is received, the transmission power calculation unit **84** sets, as the transmission power value of the terminal **50**, the second planned transmission power value included in the hello signal from the adjacent terminal on the communication route reset by the routing control unit **55**.

Referring back to FIG. **4**, the storage unit **56** stores therein the maximum transmission power value and the transmission power value that is calculated by the transmission power calculation unit **84**. The storage unit **16** also stores therein the identification information of the GW **10** that is the transmission source of the interference broadcast signal. The storage unit **16** also stores therein the identification information of the GW **10** to which the terminal **50** belongs.

Operation of Communication System

A description will be made of operations of a GW and a terminal that have above-described configurations.

Transmission Process of Interference Broadcast Signal and Control Process of Power Transmission Value of Data Signal Performed by Gateway

FIG. **7** is a flowchart for explaining a transmission process of the interference broadcast signal and a control process of the power transmission value of the data signal performed by the gateway.

In the GW **10**, the interference detection unit **15** repasts trying to detect interference (No at Step S**101**), and when interference is detected (Yes at Step S**101**), the interference detection unit **15** identifies the interfering source address (Step S**102**).

The transmission power control unit **22** determines the transmission power value of the data signal in the GW **10**, and the transmission power value of the interference broadcast signal (Step S**103**). The transmission power value of the data signal is calculated based on the hello signal sent from the interfering node. The transmission power value of the interference broadcast signal is already stored in the storage unit **16**, and is the maximum transmission power value here. For example, the transmission power control unit **22** calculates the path loss value between the GW **10** and the interfering node, and calculates the transmission power value of the data signal based on the calculated path loss value. The calculated new transmission power value is stored into the storage unit **16**.

The broadcast signal generation unit **17** generates an interference broadcast signal including the new transmission power value determined by the transmission power control unit **22** (Step S**104**).

The frame generation unit **20** and the wireless transmission processing unit **21** send the generated interference broadcast signal (Step S**105**).

When the GW **10** has received an interference broadcast signal from another GW **10**, the transmission power control unit **22** determines the transmission power value as follows. That is, the transmission power control unit **22** sets, as a new transmission power value, a larger value between the transmission power value calculated based on the path loss value between the GW **10** and the other GW **10**, and the "minimum transmission power value".

FIG. **8** is a flowchart for explaining a calculation process of the minimum transmission power value.

The required transmission power calculation unit **33** calculates path loss values between the GW **10** and transmission source terminals of received hello signals (Step S**201**).

Based on the calculated path loss values and the required receiving sensitivity, the required transmission power calculation unit **33** calculates required transmission power values (Step S**202**).

The minimum transmission power calculation unit **34** identifies the minimum value among the required transmission power values for the terminals **50** calculated by the required transmission power calculation unit **33**, and identifies the terminal **50** corresponding to the identified minimum value (Step S**203**).

The minimum transmission power calculation unit **34** calculates the minimum transmission power value based on the identified minimum value of the required transmission power values (Step S**204**).

Although the detection of interference by the interference detection unit **15** is defined to be that a data signal sent from one interfering node is detected at a certain time in the above description, the definition is not limited to this. The detection of interference by the interference detection unit **15** may be defined to be that data signals sent from one interfering node are continuously detected during a certain period starting from a first time point.

The procedure illustrated in FIG. **7** is basically executed each time the interference is detected. However, when interference by any interfering node has caused the interference broadcast signal to be sent a number of times exceeding a certain threshold value, that is, when interference by any interfering node has been detected a number of times exceeding the certain value, the interference broadcast signal indicating the interference by the interfering node may be excluded from signals to be retransmitted.

Determination Process of Communication Route and Control Process of Transmission Power Value of Data Signal Performed by Terminal

FIG. **9** is a chart for explaining a determination process of the communication route and a control process of the transmission power value of the data signal performed by the terminal.

When one of the terminals **50** has received both an interference broadcast signal from the GW **10** to which the terminal **50** belongs and an interference broadcast signal from another GW **10** (Yes at Step S**301** and Yes at Step S**302**), the routing control unit **55** basically maintains the current communication route, that is, the direct route that is directly connected to the GW **10** to which the terminal **50** belongs (Step S**303**). In this case, the transmission power control unit **61** calculates a transmission power value at which the transmission signal reaches the GW **10** to which the terminal **50** belongs but does not reach the other GW **10** (Step S**303**).

When an interference broadcast signal is received from the GW **10** to which the terminal **50** belongs, and no interference broadcast signal is received from any other GW **10** (Yes at Step S**301** and No at Step S**302**), the routing control unit **55** determines whether the terminal **50** is outside the reachable area of the GW **10** to which the terminal **50** belongs (Step S**304**).

When the routing control unit **55** determines that the terminal **50** is not outside the reachable area of the GW **10** to which the terminal **50** belongs (No at S**304**), the routing control unit **55** maintains the current communication route, that is, the direct route that directly connects the terminal **50** to the GW **10** to which the terminal **50** belongs (Step S**305**). In this case, the transmission power control unit **61** determines the first planned transmission power value included in the interference broadcast signal from the GW **10** to which the terminal **50** belongs as the transmission power value of the transmission data of the terminal **50** (Step S**305**).

When the terminal **50** is determined as outside the reachable area of the GW **10** to which the terminal **50** belongs (Yes at Step S**304**), the routing control unit **55** redetermines the communication route (Step S**306**). At this time, the routing control unit **55** determines, as the communication route, one alternative from a plurality of communication route alternatives including the other terminals **50** existing in the reachable area of the terminal **50** determined by the first planned transmission power value included in the interference broadcast signal from the GW **10** to which the terminal **50** belongs. The criterion for selecting one alternative from the communication route alternatives is the route cost that is calculated for each of the communication route alternatives. When no communication route alternative is found, the routing control unit **55** maintains the current communication route.

When the terminal **50** is determined as outside the reachable area of the GW **10** to which the terminal **50** belongs (Yes at Step S**304**), the transmission power control unit **61** deter-

mines the first planned transmission power value included in the interference broadcast signal from the GW **10** to which the terminal **50** belongs as the transmission power value of the transmission data of the terminal **50** (Step S**306**). When no communication route alternative is found, the routing control unit **55** maintains the current transmission power value.

When neither an interference broadcast signal from the GW **10** to which the terminal **50** belongs nor an interference broadcast signal from any other GW **10** is received (No at Step S**301** and No at Step S**307**), the routing control unit **55** redetermines the communication route when a certain condition is satisfied (Step S**308**). The certain condition means that the second planned transmission power value included in the hello signal sent from the first hop terminal for the terminal **50**, that is, the adjacent terminal **50** on the currently set communication route is smaller than the transmission power value that is currently set for sending the data signal of the terminal **50**.

When neither an interference broadcast signal from the GW **10** to which the terminal **50** belongs nor an interference broadcast signal from any other GW **10** is received (No at Step S**301** and No at Step S**307**), the transmission power control unit **61** determines, as the transmission power value of the terminal **50**, the second planned transmission power value included in the hello signal from the adjacent terminal on the redetermined communication route (Step S**308**).

When no interference broadcast signal is received from the GW **10** to which the terminal **50** belongs, and an interference broadcast signal is received from another GW **10** (No at Step S**301** and Yes at Step S**307**), the process terminates at that time.

As described above, according to the present embodiment, in the GW **10**, the frame generation unit **20** sends an interference broadcast signal when the interference detection unit **15** has detected interference. This interference broadcast signal includes information on the first planned transmission power value that is the transmission power value of the data signal in the GW **10** and is smaller than the maximum transmission power value. The interference broadcast signal is sent at the maximum transmission power value.

This allows the GW **10** to broadcast to the nodes included in the maximum reachable area of the GW **10** that the interference has occurred in the GW **10**. This, in turn, allows the GW **10** to notify also the interfering node of the fact that the interference has occurred, and thus to give the interfering node an opportunity to adjust the transmission power. As a result, the interference between the GWs **10** can be eliminated.

In the GW **10**, when the interference detection unit **15** has detected the interference, the transmission power control unit **22** adjusts the transmission power value of the data signal in the GW **10**. This adjustment sets the transmission power to a value at which the signal sent from the GW **10** does not reach the interfering node. For example, the transmission power value is calculated based on the receiving power value of the hello signal sent from the interfering node and on the known transmission power value of the hello signal.

This allows the GW **10** to eliminate interference given to other nodes by the GW **10** itself.

In the GW **10**, the transmission power control unit **22** determines the transmission power value of the data signal in the GW **10** based on the interference broadcast signal sent from another GW **10**. For example, the transmission power control unit **22** determines, as the transmission power value of the GW **10**, the planned transmission power value of the other GW **10** included in the interference broadcast signal sent from the other GW.

This allows the GW **10** to eliminate the interference given to other nodes by the GW **10** itself. That is because the planned transmission power value of the other GW **10** included in the interference broadcast signal sent from the other GW is a power value at which the interference from the other GW **10** to the GW **10** can be eliminated.

In the GW **10**, the transmission power control unit **22** assumes, as the lower limit value of the transmission power value of the GW **10**, the minimum value among the required transmission power values each of which is calculated for each of the terminals **50**.

This allows the GW **10** to prevent itself from being unable to communicate with any of the terminals **50**.

In the GW **10**, when the number of times of transmission of the interference broadcast signal based on the interference by any interfering node exceeds the certain value, the frame generation unit **20** excludes the interference broadcast signal based on the interference by the interfering node from signals to be retransmitted.

This allows the GW **10** to exclude, from signals to be retransmitted, the interference broadcast signal based on the interference by the interfering node that is unlikely to be eliminated, so that unnecessary signaling can be prevented.

In each of the terminals **50**, the wireless receiving processing unit **51** and the frame receiving processing unit **54** receive the interference broadcast signal sent at the maximum transmission power from the GW **10** to which the terminal **50** belongs. The interference broadcast signal is a broadcast signal indicating that the GW **10** to which the terminal **50** belongs receives a signal sent from a node other than the first hop terminals communicating with the GW **10** to which the terminal **50** belongs via direct routes, and includes information on the planned transmission power value of the data signal in the GW **10** to which the terminal **50** belongs.

This allows the terminal **50** to know that the reachable area of the GW **10** to which the terminal **50** belongs has changed. In addition, the interference broadcast signal includes the planned transmission power value of the data signal in the GW **10** to which the terminal **50** belongs after the interference broadcast signal is sent. This enables the terminal **50** to determine whether the route needs to be changed based on the interference broadcast signal from the GW **10** to which the terminal **50** belongs. In other words, the terminal **50** can determine whether the terminal **50** is outside the reachable area of the GW **10** to which the terminal **50** belongs.

In the terminal **50**, the wireless receiving processing unit **51** and the frame receiving processing unit **54** receive the hello signal sent at the maximum transmission power from a node other than the terminal **50**. The hello signal includes the type information and the identification information of the other node, and information on the planned transmission power value of the data signal in the other node.

This allows the terminal **50** to determine the route based on the planned transmission power value of the other node.

In the terminal **50**, when the terminal **50** is determined as outside the reachable area of the GW **10** to which the terminal **50** belongs, the routing control unit **55** identifies communication route alternatives each including, as the adjacent terminals, each of a plurality of terminals of which a required transmission power value is smaller than the planned transmission power value included in the interference broadcast signal from the GW **10** to which the terminal **50** belongs. Then, the routing control unit **55** determines, as the communication route, the route alternative having the smallest route cost among the identified route alternatives. In this case, the transmission power control unit **61** sets, as the transmission power value of the terminal **50**, the planned transmission

power value included in the interference broadcast signal from the GW **10** to which the terminal **50** belongs.

This allows the terminal **50** to maintain the communication with the GW **10** to which the terminal **50** belongs through the most efficient communication route, and to prevent itself from interfering the GW **10** to which the terminal **50** belongs.

In the terminal **50**, when the terminal **50** is determined as included in both the reachable area of the GW **10** and the reachable area of another GW **10**, the transmission power control unit **61** sets the transmission power value of the terminal **50** to a value smaller than the required transmission power value between the terminal **50** and the other GW **10**.

This allows the terminal **50** to eliminate the interference given to the other GW **10** by the terminal **50**.

In the terminal **50**, when the terminal **50** is determined as included in neither the reachable area of the GW **10** to which the terminal **50** belongs nor the reachable area of any other GW **10**, the routing control unit **55** performs the following process. That is, the routing control unit **55** identifies a plurality of route alternatives each including, as the adjacent terminals, each of a plurality of terminals of which a required transmission power value is smaller than the planned transmission power included in the hello signal from the adjacent terminal on the currently set communication route. Then, the routing control unit **55** determines, as the communication route, the route alternative having the smallest route cost among the identified route alternatives.

This allows the terminal **50** to maintain the communication with the GW **10** to which the terminal **50** belongs through the most efficient communication route regardless of any change in the state of communication with the current adjacent terminal caused by the adjustment of the reachable area by the GW **10**.

[b] Other Embodiments

1. Although the first embodiment describes the terminal **50** that resets the communication route and sets the transmission power value using as a trigger the event of receiving the interference broadcast signal from any of the GWs **10**, the timing of resetting the communication route and setting the transmission power value is not limited to this. For example, the terminal **50** may normally reset the communication route and set the transmission power value at certain intervals, and temporarily use as a trigger the event of receiving the interference broadcast signal from the GW **10** to reset the communication route and set the transmission power value.

2. Although the broadcast signal extraction unit **71** and the broadcast signal extraction unit **81** are described as separate functional units in the first embodiment, the configuration thereof is not limited to this. The broadcast signal extraction unit **71** and the broadcast signal extraction unit **81** may be implemented as one functional unit. In the same way, the hello signal extraction unit **72** and the hello signal extraction unit **82** may be implemented as one functional unit. The required transmission power calculation unit **73** and the required transmission power calculation unit **83** may also be implemented as one functional unit.

3. The GWs **10** and the terminals **50** of the first embodiment can be implemented by the following hardware configurations.

FIG. **10** is a diagram illustrating the hardware configuration of the gateway. As illustrated in FIG. **10**, the GW **10** includes, as constituent elements of the hardware, a memory **10***a*, a central processing unit (CPU) **10***b*, and a radio frequency (RF) circuit **10***c*. The RF circuit **10***c* includes an antenna. The memory **10***a* is composed of, for example, a random access memory (RAM) such as a synchronous dynamic random access memory (SDRAM), a read-only memory (ROM), and a flash memory. The storage unit **16** is implemented by the memory **10***a*. The transmission control unit **13**, the frame receiving processing unit **14**, the interference detection unit **15**, the broadcast signal generation unit **17**, the data processing unit **18**, the hello signal generation unit **19**, the frame generation unit **20**, and the transmission power control unit **22** are implemented by integrated circuits such as the CPU **10***b*. The wireless receiving processing unit **11**, the carrier detection unit **12**, and the wireless transmission processing unit **21** are implemented by the RF circuit **10***c*.

FIG. **11** is a diagram illustrating a hardware configuration of the multi-hop communication terminal. As illustrated in FIG. **11**, the terminal **50** includes, as hardware, a memory **50***a*, a CPU **50***b*, and an RF circuit **50***c*. The RF circuit **50***c* includes an antenna. The memory **50***a* is composed of, for example, a RAM such as an SDRAM, a ROM, and a flash memory. The transmission control unit **53**, the frame receiving processing unit **54**, the routing control unit **55**, the data processing unit **57**, the hello signal generation unit **58**, the frame generation unit **59**, and the transmission power control unit **61** are implemented by integrated circuits such as the CPU **50***b*. The wireless receiving processing unit **51**, the carrier detection unit **52**, and the wireless transmission processing unit **60** are implemented by the RF circuit **50***c*.

The various processes described in the first embodiment can be implemented by executing prepared programs in a computer. For example, programs corresponding to the respective processes executed by the transmission control unit **13**, the frame receiving processing unit **14**, the interference detection unit **15**, the broadcast signal generation unit **17**, the data processing unit **18**, the hello signal generation unit **19**, the frame generation unit **20**, and the transmission power control unit **22** can be recorded in the memory **10***a*, and the programs can be read into the CPU **10***b* and function as the processes. In addition, programs corresponding to the respective processes executed by the transmission control unit **53**, the frame receiving processing unit **54**, the routing control unit **55**, the data processing unit **57**, the hello signal generation unit **58**, the frame generation unit **59**, and the transmission power control unit **61** can be recorded in the memory **50***a*, and the programs can be read into the CPU **50***b* and function as the processes.

According to an aspect disclosed herein, interference between gateways can be suppressed, and terminals directly communicating with the gateways can maintain the communication.

All examples and conditional language recited herein are intended for pedagogical purposes of aiding the reader in understanding the invention and the concepts contributed by the inventor to further the art, and are not to be construed as limitations to such specifically recited examples and conditions, nor does the organization of such examples in the specification relate to a showing of the superiority and inferiority of the invention. Although the embodiments of the present invention have been described in detail, it should be understood that the various changes, substitutions, and alterations could be made hereto without departing from the spirit and scope of the invention.

What is claimed is:

1. A multi-hop communication terminal that communicates with a gateway to which the multi-hop communication terminal belongs via a communication route that is an indirect

route including at least one other terminal or a direct route, the multi-hop communication terminal comprising:

a receiving unit that receives:

a first broadcast signal that is sent at a first transmission power value from the gateway to which the multi-hop communication terminal belongs and that includes information on a first planned transmission power value of a data signal in the gateway to which the multi-hop communication terminal belongs, the first planned transmission power value being smaller than the first transmission power value; and

a hello signal that includes type information and identification information of a node other than the terminal, and information on a second planned transmission power value of a data signal in the other node;

a routing control unit that determines the communication route based on the received first broadcast signal and the received hello signal;

a power control unit that determines a second transmission power value of a data signal in the terminal based on the received first broadcast signal, the received hello signal, and the determined communication route; and

a calculation unit that calculates a path loss value between the terminal and a transmission source node of the received first broadcast signal or the received hello signal based on the received first broadcast signal or the received hello signal, and calculates a required transmission power value based on the calculated path loss value and a required receiving power value; wherein

when a second broadcast signal is not received from a gateway other than the gateway to which the multi-hop communication terminal belongs, and when the first planned transmission power value is larger than the required transmission power value between the terminal and the gateway to which the multi-hop communication terminal belongs that has been calculated by the calculation unit, the power control unit determines the first planned transmission power value as the second transmission power value.

2. A multi-hop communication terminal that communicates with a gateway to which the multi-hop communication terminal belongs via a communication route that is an indirect route including at least one other terminal or a direct route, the multi-hop communication terminal comprising:

a receiving unit that receives:

a first broadcast signal that is sent at a first transmission power value from the gateway to which the multi-hop communication terminal belongs and that includes information on a first planned transmission power value of a data signal in the gateway to which the multi-hop communication terminal belongs, the first planned transmission power value being smaller than the first transmission power value; and

a hello signal that includes type information and identification information of a node other than the terminal, and information on a second planned transmission power value of a data signal in the other node;

a routing control unit that determines the communication route based on the received first broadcast signal and the received hello signal;

a power control unit that determines a second transmission power value of a data signal in the terminal based on the received first broadcast signal, the received hello signal, and the determined communication route; and

a calculation unit that calculates a path loss value between the terminal and a transmission source node of the received first broadcast signal or the received hello signal based on the received first broadcast signal or the received hello signal, and calculates a required transmission power value based on the calculated path loss value and a required receiving power value; wherein

when a second broadcast signal is not received from a gateway other than the gateway to which the multi-hop communication terminal belongs, and when the first planned transmission power value is smaller than the required transmission power value between the terminal and the gateway to which the multi-hop communication terminal belongs that has been calculated by the calculation unit, the routing control unit identifies a plurality of route alternatives each including, as an adjacent terminal, each of a plurality of terminals of which the required transmission power value calculated by the calculation unit is smaller than the first planned transmission power value, and sets, as the communication route, the route alternative having smallest route cost among the identified route alternatives; and

the power control unit determines the first planned transmission power value as the second transmission power value.

3. A multi-hop communication terminal that communicates with a gateway to which the multi-hop communication terminal belongs via a communication route that is an indirect route including at least one other terminal or a direct route, the multi-hop communication terminal comprising:

a receiving unit that receives:

a first broadcast signal that is sent at a first transmission power value from the gateway to which the multi-hop communication terminal belongs and that includes information on a first planned transmission power value of a data signal in the gateway to which the multi-hop communication terminal belongs, the first planned transmission power value being smaller than the first transmission power value; and

a hello signal that includes type information and identification information of a node other than the terminal, and information on a second planned transmission power value of a data signal in the other node;

a routing control unit that determines the communication route based on the received first broadcast signal and the received hello signal; and

a power control unit that determines a second transmission power value of a data signal in the terminal based on the received first broadcast signal, the received hello signal, and the determined communication route,

wherein

the receiving unit receives a second broadcast signal from a gateway other than the gateway to which the multi-hop communication terminal belongs;

the multi-hop communication terminal further comprises a calculation unit that calculates a path loss value between the terminal and a transmission source node of the received first broadcast signal, the received second broadcast signal, or the received hello signal based on the received first broadcast signal, the received second broadcast signal, or the received hello signal, and calculates a required transmission power value based on the calculated path loss value and a required receiving power value; and

the power control unit determines the second transmission power value to be a value smaller than the required transmission power value between the other gateway and the terminal that has been calculated by the calculation unit.

4. A multi-hop communication terminal that communicates with a gateway to which the multi-hop communication terminal belongs via a communication route that is an indirect route including at least one other terminal or a direct route, the multi-hop communication terminal comprising:

a receiving unit that receives:

a first broadcast signal that is sent at a first transmission power value from the gateway to which the multi-hop communication terminal belongs and that includes information on a first planned transmission power value of a data signal in the gateway to which the multi-hop communication terminal belongs, the first planned transmission power value being smaller than the first transmission power value; and

a hello signal that includes type information and identification information of a node other than the terminal, and information on a second planned transmission power value of a data signal in the other node;

a routing control unit that determines the communication route based on the received first broadcast signal and the received hello signal; and

a power control unit that determines a second transmission power value of a data signal in the terminal based on the received first broadcast signal, the received hello signal, and the determined communication route; and

a calculation unit that calculates a path loss value between the terminal and a transmission source node of the received hello signal based on the received hello signal, and calculates a required transmission power value based on the calculated path loss value and a required receiving power value; wherein

when neither the first broadcast signal from the gateway to which the multi-hop communication terminal belongs nor a second broadcast signal from a gateway other than the gateway to which the multi-hop communication terminal belongs is received, the routing control unit identifies a plurality of route alternatives each including, as an adjacent terminal, each of a plurality of terminals of which the required transmission power value calculated by the calculation unit is smaller than the second planned transmission power included in the hello signal sent from the adjacent terminal on the currently set communication route, and sets, as the communication route, the route alternative having smallest route cost among the identified route alternatives.

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